

Grant Title:

Using Natural Language Processing to Evaluate whether Colonoscopy Follow-up Recommendations are Consistent With Guidelines

Principal Investigators:

Ateev Mehrotra, MD, MPH, MS

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In the relevant background section we describe Dr. Mehrotra's unique position and why he represents both RAND and University of Pittsburgh on this proposal

Carrie Farmer Teh, PhD

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Robert E Schoen, MD, MPH

(University of Pittsburgh, Division of Gastroenterology, Mezzanine Level, C Wing, PUH, 200 Lothrop St. Pittsburgh, PA 15213, 412-647-8666, rschoen@pitt.edu)

Key Personnel and Role:

Hendrik Harkema, PhD (Post-doctoral fellow in Department of Biomedical Informatics, University of Pittsburgh, expert in natural language processing, programming)

Melissa Saul, MSc (Director, Clinical Research Informatics Service, University of Pittsburgh, expert in natural language processing, obtaining clinical records)

Evan S Dellon, MD, MPH (Assistant Professor, Division of Gastroenterology and Hepatology, Department of Medicine, University of North Carolina School of Medicine, clinical expertise in colonoscopy)

ABSTRACT

One barrier to improving the quality of healthcare is the shortage of readily available quality measures. To date, healthcare quality has generally been measured using analysis of administrative claims or manual record reviews, both of which have key limitations. Administrative claims lack the clinical details that are important to providers and patients. Medical record reviews are time-consuming and expensive, and therefore not routinely feasible on a large scale. Recent advances in health information technology, however, may provide opportunities for routine clinical quality measurement. Combining electronic medical records (EMR), increasingly used by healthcare providers, and natural language processing (NLP) tools, developed to translate free text into structured data, creates the possibility of a new NLP-based method for measuring the quality of care.

We propose to apply this novel technique to measure the quality of follow-up recommendations after screening colonoscopy. Evidence shows that clinicians inappropriately perform screening colonoscopy in excess of guidelines, which in turn harms access to care and increases healthcare costs. Because of their format, colonoscopy reports make an ideal target for NLP analyses. We propose to develop a NLP-based program (the C-QUAL tool) to analyze colonoscopy reports to judge whether follow-up recommendations are consistent with guidelines. We will then test the C-QUAL tool against the gold standard of an expert clinician. This project will provide the preliminary data for a grant to use the C-QUAL tool to measure the quality of a large national sample of colonoscopy reports.

Relevant background of investigators

Ateev Mehrotra is an internist and health services researcher. His research interests focus on measuring the quality of healthcare and how quality measures can be used in policy applications. He has applied administrative claims-based quality measures in numerous projects. In a project on retail clinics he developed new quality measures based on clinical guidelines for pharyngitis and otitis media. He has also studied the impact of public reporting of quality data and pay-for-performance incentives. In the proposed project, he will be involved in all stages of the project working closely with Hendrik Harkema in developing and training the C-QUAL tool.

Dr. Mehrotra holds a unique joint position at University of Pittsburgh and RAND, and he splits his time equally. For the purposes of this RUPHI grant he represents both sites and will be the overall principal investigator collaborating with all investigators. Because he is a recipient of a KL2 award from the NIH, Dr. Mehrotra will not be requesting salary support in the proposed project.

Carrie Farmer Teh is an Associate Policy Researcher at RAND. Dr. Teh holds a Ph.D. in Health Policy from Harvard University. She has expertise in the measurement and assessment of healthcare quality. As part of a study funded by a large managed behavioral healthcare organization, Dr. Teh translated depression treatment guidelines into quality measures for use with administrative data. In a NIH funded study, she used longitudinal survey data to evaluate depression care quality for individuals with comorbid chronic health conditions and investigated the predictive validity of depression quality measures for social and clinical outcomes. She has two ongoing projects that use medical record data to assess quality of care. In one project she is evaluating the quality of mental healthcare in the Veteran Affairs system. In the other she is translating guidelines into quality measures for the care of bipolar disorder. In the proposed project, she will work with Dr. Mehrotra to operationalize medical record-based quality measures for colonoscopy follow-up, develop the ontology for the C-QUAL tool, and analyze C-QUAL's concordance with manual abstraction methods.

Robert Schoen is a gastroenterologist and clinical researcher at the University of Pittsburgh. His research interests are in early detection and prevention of colorectal cancer. He is a principal investigator in the PLCO cancer screening trial, which is a randomized trial evaluating flexible sigmoidoscopy and is an investigator for the NCI sponsored Early Detection Research Network. In previous work he has described the overutilization of colonoscopy in clinical practice. In the proposed project, he will provide clinical expertise on colonoscopy and senior leadership on the methodological design and analyses. His knowledge of how colonoscopy reports are created in UPMC affiliated clinics will also be invaluable.

Hendrik Harkema is a Natural Language Processing (NLP) researcher in the Department of Biomedical Informatics. Dr. Harkema has been involved in a wide range of NLP projects in the biomedical and clinical domain. One of his projects concerned the construction of an information extraction engine for clinical reports. As part of this project Dr. Harkema adapted modules for named entity recognition, syntactic and semantic analysis, and relationship extraction to the clinical domain. In another project Dr. Harkema contributed to the design of a system for extracting gene and protein interactions from scientific text. Currently, Dr. Harkema is working on an NLP system for indexing clinical concepts and integrating textual modifiers such as negation, uncertainty, and temporality in order to identify acute clinical conditions from Emergency Department reports. Another of Dr. Harkema's current projects is the development of an application that uses speech recognition and NLP to chart the results of a dental exam from a dentist's dictation in real time. In the proposed project Dr. Harkema will be responsible for the design and implementation of the NLP components.

Melissa Saul is the director of the Clinical Research Information Service (CRIS) which provides both data warehouse/data mining through the Medical Archival System (MARS) and de-identification services through De-ID, the University of Pittsburgh's de-identification software. She is an adjunct assistant professor of health information management at the School of Health and Rehabilitation Sciences and also serves as informatics director at the Center for Pharmacoinformatics and Outcomes Research in the School of Pharmacy. She is a founding member of the MARS development team. MARS is the University of Pittsburgh Medical Center's data repository for clinical and financial data. She has served as a trusted broker for over 300 IRB approved projects throughout the School of the Health Sciences and has extensive experience in data extraction and management of large data sets. In the proposed project, Ms. Saul will help with obtaining, linking, and de-identifying the data. Her expertise in how clinical records are structured throughout the UPMC system will also be critical. Because of her affiliation with the University of Pittsburgh's CTSI, Ms. Saul will not be requesting salary support in this project.

Evan Dellon is a gastroenterologist and clinical researcher at the University of North Carolina. A recipient of a KL2 award and funding from the American College of Gastroenterology, his research interests include eosinophilic esophagitis and advanced endoscopy, including quality assessment and application of new technologies. He has recently published two papers investigating the effect of endoscopy nurse experience on screening colonoscopy outcomes including complications and polyp detection rates. In the proposed project, he will provide clinical expertise on colonoscopy, and also will be one of the people providing the manual "gold standard" for colonoscopy follow-up recommendations. In addition, his affiliation with UNC will help set the stage for future collaborations at other sites around the nation. Because he is a recipient of a KL2 award from the NIH, Dr. Dellon will not be requesting salary support in the proposed project.

BIOGRAPHICAL SKETCH

NAME Ateev Mehrotra	POSITION TITLE Assistant Professor, University of Pittsburgh School of Medicine, Policy Analyst, RAND Corporation
eRA COMMONS USER NAME mehrotra	

EDUCATION/TRAINING			
INSTITUTION AND LOCATION	DEGREE (if applicable)	YEAR(s)	FIELD OF STUDY
Massachusetts Institute of Technology, Cambridge, MA	S.B.	1990-1994	Environmental Engineering
University of California, Berkeley, CA	M.P.H.	1997-1998	Biostatistics/ Epidemiology
University of California, San Francisco, CA	M.D.	1994-1999	Medicine
Harvard School of Public Health, Boston, MA	M.Sc.	2004-2006	Epidemiology

Positions:

1999–2004	Harvard Combined Medicine/Pediatrics Residency Program, Boston, MA
2001–2002	Project Fellow in Health Economics Group, Institute for Health Policy Studies, University of California, San Francisco
2004-2006	Harvard Medical School Faculty Development and Fellowship Program in General Internal Medicine, Boston, MA
2006-present	Assistant Professor of Medicine, University of Pittsburgh School of Medicine, Division of General Internal Medicine, Pittsburgh, PA
2006-present	Policy Analyst, RAND Pittsburgh, Pittsburgh, PA
2008-present	Secondary Appointment in Clinical and Translational Research, University of Pittsburgh

Honors:

2002 & 2003	Cambridge Hospital Pediatric Teaching Award
2004	Harvard Medical School Class of 2004 Resident Teaching Award
2004	Zeljco Nikolic Memorial Award – Awarded to MGH pediatric resident who best exemplifies the qualities of a generous spirit and intellectual curiosity
2007	Best Abstract, Academy Health Annual Research Conference
2008 ,2009	Outstanding Abstract, Academy Health Annual Research Conference
2008	Milton W. Hamolsky Award for Outstanding Scientific Presentation by a Junior Faculty member at Annual Meeting of Society of General Internal Medicine

Selected peer-reviewed publications (in chronological order).

1. White MC, **Mehrotra A**, Menendez E, Estes M, Goldenson J, Tulskey J, Jail Inmates and HIV Care: Provision of Antiretroviral Therapy and *Pneumocystis carinii* Pneumonia Prophylaxis., *JP Int J STD AIDS* 2001 Jun;12(6):380-5
2. **Mehrotra A**, Bodenheimer,T, Dudley RA. Employer Efforts To Measure And Improve Hospital Quality: Determinants of Success. *Health Affairs*, 2003; 22(2):60-71

3. **Mehrotra A**, Dudley RA, Luft HS. What's Behind the Health Expenditure Trends? *Annual Review of Public Health*, 2003. 24:385–412
4. **Mehrotra A**, Grier S, Dudley RA. Relationship Between Health Plan Advertising and Market Incentives: Evidence of Risk Selective Behavior *Health Affairs*, 2006; 25(3):759-65.
5. **Mehrotra A**, Epstein AM, Rosenthal MB. Do integrated medical groups provide higher-quality medical care than individual practice associations? *Annals of Internal Medicine*. 2006 Dec 5;145:826-33.
6. **Mehrotra A**, Pearson S, Coltin K, Kleinman KP, Singer J, Rabson B, Schneider EC, The Response of Physician Groups to Pay-for-Performance Incentives *American Journal of Managed Care*. 2007 May;13(5):249-55.
7. **Mehrotra A**, Zaslavsky A, Ayanian J, Preventive Health Examinations and Preventive Gynecological Examinations in the United States. *Archives of Internal Medicine*. 2007;167(17):1876-1883
8. **Mehrotra A**, McNeil BJ, Landon BE, "Congestive Heart Failure Disease Management in Medicare Managed Care" *American Heart Journal* 2007; 154(6): 1153-1159
9. **Mehrotra A**, Markowitz LK, Ayanian J, Implementation of Open Access Scheduling: A Cautionary Tale *Annals of Internal Medicine*. 2008;148:915-922.
10. **Mehrotra A**, Wang MC, Adams JL, Lave JR, McGlynn EA, A Comparison of Patient Visits to Retail Clinics, Primary Care Physicians, and Emergency Departments, *Health Affairs*, 2008, 27(5): 1272-1282
11. **Mehrotra A**, Damberg CL, Sorbero ME, Teleki, SS, Pay-for-Performance in the Hospital Setting: What is the State of the Evidence?" *American Journal of Medical Quality*, OnlineFirst, published on December 10, 2008 as doi:10.1177/1062860608326634
12. Friedberg, M, **Mehrotra A**, Linder JA, Has the Hospital Quality Alliance Measure on Antibiotic timing in Pneumonia Led to Unintended Adverse Consequences, *American Journal of Managed Care*, 2009.15(2):104-9
13. Hausmann LRM, Ibrahim SA, **Mehrotra A**, Nsa W, Bratzler DW, Mor MK, Fine MJ. Between-Hospital and Within-Hospital Racial and Ethnic Disparities in Community-Acquired Pneumonia Treatment and Mortality, *Medical Care*, In Press
14. Wang, MC, Ryan G, McGlynn EA, **Mehrotra A**, What Makes Retail Clinics Attractive: Lessons from Patients' Experience, *American Journal of Medical Quality*. In Press
15. Lee BY, **Mehrotra A**, Burns RM, Harris, KM, Alternative Vaccination Locations: Who Uses Them and Can They Increase Flu Vaccination Rates? *Vaccine*. In Press
16. Rudavsky R, **Mehrotra A**, The Socio-Demographic Characteristics of the Communities Served by Retail Clinics. *Journal of the American Board of Family Medicine*, In Press
17. **Mehrotra A**, Liu H, Wang MC, Lave J, Thygeson NM, Solberg LI, McGlynn EA, Retail Clinic Care Costs and Quality as Compared to Other Medical Settings, *Annals of Internal Medicine*, In Press
18. Hussey, P, Sorbero ME, **Mehrotra A**, Damberg CL. Using Episodes of Care as a Basis for Performance Measurement and Payment, *Health Affairs*, In Press
19. Rudavsky R, Pollack CE, **Mehrotra A**. The Geographic Distribution, Ownership, and Scope of Practice at Retail Clinics. *Annals of Internal Medicine*, In Press

Research Support.

Ongoing

An Evaluation of Consumer-Directed Healthcare

Role: Career Development Award

Goals: The award has supported by salary in my previous research on retail clinics as well as research on physician cost and quality profiling. It has also supported further research training.

Funding Agency: National Institutes of Health (NIH) Multidisciplinary Clinical Research Scholars Program (Roadmap K12)
Dates: 2007 – 2011

Cost-efficiency Profiling of Physicians or Physician Groups

Role: Principal Investigator

Goals: We are using administrative data to profile individual physicians and physician groups on their relative costs. The goal is to help policymakers understand the relative strengths and weakness of profiling physician groups as opposed to individual physicians.

Funding Agency: Massachusetts Medical Society

Dates: 2007-2009

The Quality of the Specialty Referral Process

Role: Principal Investigator

Goals: A systematic review of the literature on how often referrals are appropriate and the quality of the communication between primary care providers and physicians

Funding Agency: California HealthCare Foundation

Dates: 2008-2009

The Risk of Miscategorizing Physicians with Cost and Quality Profiling

Role: Co-Investigator

Goals: Health plans are increasingly using individual physician cost and quality profiles. In this study we are modeling how often these profiles inappropriately categorize a physician as “high cost” or because the profiles have low reliability.

Funding Agency: American Medical Association

Dates: 2008-2009

Computer-Assisted Provision of Hormonal Contraception

Role: Co-Investigator

Goals: A randomized control trial to increase the provision of contraception via the use of a computer kiosk placed in the waiting room of retail clinics, urgent care clinics, and emergency departments.

Funding Agency: Society for Family Planning

Dates: 2008-2010

Recently Completed

Retail Clinics: Disruptive Innovation or Just Plain Disruption?

Role: Principal Investigator

Goals: To compare the quality and costs of care at retail clinics compared to physician offices and EDs as well as to complete qualitative interviews with patients at retail clinics.

Funding Agency: California HealthCare Foundation

Dates: 2007-2008

Retail Health Clinics: Who do they target?

Role: Principal Investigator

Goals: To better understand the geographic distribution of retail clinics and the population they serve.

Funding Agency: California HealthCare Foundation

Dates: 2008

BIOGRAPHICAL SKETCH

NAME Robert E. Schoen, MD, MPH	POSITION TITLE Professor of Medicine and Epidemiology		
eRA COMMONS USER NAME rschoen			
EDUCATION/TRAINING			
INSTITUTION AND LOCATION	DEGREE (if applicable)	YEAR(s)	FIELD OF STUDY
Columbia College, NY	AB	1979	Psychology
Columbia University College of P & S, NY	MD	1984	Medicine
University of Pittsburgh, Pittsburgh, PA	MPH	1994	Epidemiology
Albert Einstein College of Medicine, NY		1987	Resident/Internal Medicine
Cornell University Medical College, NY		1988	Fellow/General Medicine
Albert Einstein College of Medicine, NY		1991	Fellow/Gastroenterology

A. Positions and Honors

1988 - 1989	Instructor, Division of General Internal Medicine, Cornell University Medical College, NY, NY
1991 - 1992	Instructor, Division of Gastroenterology and Hepatology, University of Pittsburgh Medical Center
1992 - 2000	Assistant Professor of Medicine, Division of Gastroenterology and Hepatology, U. of Pittsburgh
1993 - 1995	Fellow in Cancer Prevention, University of Pittsburgh Medical Center
1996 - 2000	Assistant Professor of Epidemiology, Graduate School of Public Health, U. of Pittsburgh
1999 - present	Director, Colorectal and GI Cancer Prevention and Control Research, Pittsburgh Cancer Institute
2000 - 2005	Associate Professor of Medicine and Epidemiology
2005 -	Professor of Medicine and Epidemiology

Awards and Other Professional Activities

1987	Diplomate, American Board of Internal Medicine
1991	Diplomate, Gastroenterology
1996 - 1998	Chairman, Polyp Subcommittee of the Polyp Prevention Trial
1999 - 2009	Abstract Review Committee, Screening for GI Malignancies, General Clinical and Epidemiology, American Gastroenterological Association
2002 - present	Chairman, Colon Organ Site Committee, PLCO Trial

B. Selected Peer Reviewed Publications (of 85)

1. **Schoen RE**, Frishman WH, Shamon H. Hormonal and metabolic effects of calcium channel antagonists in man. Am J Med 1988; 84:492-504. (PMID 2450457)
2. **Schoen RE**, Weissfeld JL, Kuller LH. Are women with breast, endometrial, or ovarian cancer at increased risk for colorectal cancer? Am J Gastroenterol 1994; 89:835-842. (PMID8198091)
3. **Schoen RE**, Weissfeld JL, Kuller LH. Sigmoidoscopy use among primary care physicians. Preventive Medicine 1995; 3:249-254. (PMID7644447)
4. **Schoen RE**, Evans RW, Sankey SS, Weissfeld JL, Kuller L. Does visceral adipose tissue differ from subcutaneous adipose tissue in fatty acid content? Int J Obes 1996; 20:346-352. (PMID8680462)
5. **Schoen RE**, Gerber LD, Margulies C. The pathologic measurement of polyp size is preferable to the endoscopic estimate. Gastrointest Endosc 1997; 46:492-496. (PMID 9434214)
6. **Schoen RE**, Corle D, Cranston L, Weissfeld JL, Lance P, Burt R, Iber F, Shike M, Kikendall JW, Hasson M, Lewin KJ, Appleman HD, Paskett E, Selby JV, Lanza E, Schatzkin A, for the Polyp Prevention Trial. Is colonoscopy needed for the non-advanced adenoma found on sigmoidoscopy? Gastroenterology 1998; 115:533-541. (PMID 9721149)

7. **Schoen RE**, Tangen CM, Kuller LH, Burke GL, Cushman M, Tracy RP, Dobs A, Savage PJ. Increased blood glucose and insulin, body size, and incident colorectal cancer. J Natl Cancer Inst 1999; 91:1147-1154. (PMID 10393723)
8. **Schoen RE**, Weissfeld JL, Bowen, NJ, Switzer G, Baum A. Patient satisfaction with screening flexible sigmoidoscopy. Archives Intl Medicine 2000;160:1790-1796. (PMID 10871972)
9. Schatzkin A, Lanza E, Corle D, Lance P, Iber F, Caan B, Shike M, Weissfeld J, Burt R, Cooper MR, Kikendall JW, Cahill J, Freedman L, Marshall J, **Schoen RE**, Slattery M. Lack of effect of a low fat, high-fiber diet on the recurrence of colorectal adenomas. New England Journal of Medicine 2000;342(16):1149-1155. (PMID 10770979)
10. Weissfeld JL, Ling BS, **Schoen RE**, Bresalier RS, Riley T, Prorok P. Adherence to repeat screening flexible sigmoidoscopy in the prostate, lung, colorectal, and ovarian (PLCO) cancer screening trial. Cancer 2002;94: 2569-76. (PMID 12173322)
11. Brünagel G, Vietmeier BN, Bauer AJ, **Schoen RE**, Getzenberg RH. Identification of Nuclear Matrix Protein Alterations Associated with Human Colon Cancer. Cancer Research 2002;62:2437-42. (PMID 11956108)
12. **Schoen RE**, Schragin J, Weissfeld JL, Thaete FL, Evans RW, Rosen CJ, Kuller LH. Lack of association between adipose tissue distribution and IGF-1 and IGFBP-3 in men and women. Cancer, Epidemiology, and Biomarkers 2002;11:581-6. (PMID 12050100)
13. **Schoen RE**. The case for population-based screening for colorectal cancer. Nature Reviews – Cancer 2002, 2:65. (PMID 11902587)
14. Trauth JM, Ling BS, Weissfeld JL, **Schoen RE**, Hayran M. Using the transtheoretical model to stage screening behavior for colorectal cancer. Health Education & Behavior 2003;30:322-36.
15. **Schoen RE**. Surveillance after Positive and Negative Colonoscopy Examinations: Issues, Yields, and Use. Am J Gastroenterol 2003; 98:1237-46. (PMID12818263)
16. Pinsky PF, **Schoen RE**, Weissfeld JL, Bresalier RS, Hayes RB, Gohagan JK. Predictors of Advanced Proximal Neoplasia in Persons with Abnormal Screening Flexible Sigmoidoscopy. Clinical Gastroenterology and Hepatology 2003; 1:103-110. (PMID 15017502)
17. Brünagel G, **Schoen RE**, Bauer AJ, Vietmeier BN, Getzenberg RH. Nuclear matrix protein alterations associated with colon cancer metastasis to the liver. Clinical Cancer Research 2002; 8:3039-45. (PMID 12374670)
18. **Schoen RE**, Pinsky PF, Weissfeld JL, Bresalier RS, Church T, Prorok P, Gohagan JK. Results of Repeat Sigmoidoscopy Three Years After a Negative Examination. JAMA 2003;290:41-48. (PMID 128337710)
19. Brunagel G, **Schoen RE**, Getzenberg RH. Colon cancer specific nuclear matrix protein alterations in human colonic adenomatous polyps. Journal of Cellular Biochemistry 2004;91:365-74. (PMID 14743395)
20. Sass DA, **Schoen RE**, Weissfeld JL, Weissfeld L, Thaete FL, Kuller LH, McAdams M, Lanza E, Schatzkin A. Relationship of Visceral Adipose Tissue to Recurrence of Adenomatous Polyps. Am J Gastroenterol 2004;99:687. (PMID 15089903)
21. Peters U, Chatterjee N, Yeager M, Chanock S, **Schoen RE**, McGlynn KA, Church TR, Weissfeld J, Schatzkin A, Hayes RB. Association of Genetic Variants in the Calcium-sensing Receptor with Risk of Colorectal Adenoma. Cancer Epidemiol Biomarkers Prev 2004;13:2181-6 (PMID 15598778)
22. Pabby A, **Schoen RE**, Weissfeld JL, Burt R, Kikendall JW, Lance MP, Shike M, Lanza E, Schatzkin A. Analysis of colorectal cancer occurrence during surveillance colonoscopy in the dietary polyp prevention trial. Gastrointest Endoscopy 2005;61:385-91. (PMID 15758908)
23. Ouyang DL, Chen JJ, Getzenberg RH, **Schoen RE**. Non-Invasive Testing for Colorectal Cancer: A Review. Am J Gastroenterol 2005; 100: 1393-1403. (PMID 15929776)
24. Pinsky PF, **Schoen RE**, Weissfeld JL, Kramer B, Hayes RB, Yokochi Y, for the PLCO Project Team. Variability in Flexible Sigmoidoscopy Performance Among Examiners in a Screening Trial. Clinical Gastroenterology and Hepatology 2005; 3:792-97. (PMID 16234008)
25. Weissfeld JL, **Schoen RE**, Pinsky PF, Bresalier RS, Church T, Yurgalevitch S, Austin JH, Prorok PC, Gohagan JK, for the PLCO Project Team. Flexible Sigmoidoscopy in the PLCO Cancer Screening Trial: Results from the Baseline Examination. Journal of the National Cancer Institute 2005; 97:989-97. (PMID 15998952)
26. Levin TR, Farraye FA, **Schoen RE**, Hoff G, Atkin WS, Bond JH, Winawer SJ, Burt RW, Johnson DA, Kirk LM, Litin SC, Rex DK. Quality In The Technical Performance Of Screening Flexible Sigmoidoscopy; Recommendations Of The U.S. Multi-Society Task Force On Colorectal Cancer. Gut 2005; 54:807-13. (PMID 15888789)
27. **Schoen RE**, Weissfeld JL, Kuller LH, Thaete FL, Evans RW, Hayes RB, Rosen CJ. Insulin-Like Growth Factor-1 and Insulin are Associated with the Presence and Advancement of Adenomatous Polyps. Gastroenterology 2005; 129:464-75. (PMID 16083703)

28. Gupta AK, Pretlow TP, **Schoen RE**. Aberrant Crypt Foci: What We Know and What We Need To Know. Clinical Gastroenterology and Hepatology 2007; 5(5):526-33. (PMID 17433788)
29. Hur C, Chung DC, **Schoen RE**, Gazelle GS. The Management of Small Polyps Found by Virtual Colonoscopy: Results of a Decision Analysis. Clinical Gastroenterology and Hepatology 2007;5:237-44. (PMID 17296532)
30. **Schoen RE**, Weissfeld JL, Pinsky PF, Riley T. Yield of Advanced Adenoma and Cancer Based on Polyp Size Detected at Screening Flexible Sigmoidoscopy. Gastroenterology 2006; 131:1683-89. (PMID 17188959)
31. Lanas A, Baron JA, Sandler RS, Horgan K, Bolognese J, Oxenius B, Quan H, Watson D, Cook TJ, **Schoen R**, Burke C, Loftus S, Niv Y, Ridell R, Morton D, Bresalier R. Peptic Ulcer And Bleeding Events Associated With Rofecoxib In a 3-Year Colorectal Adenoma Chemoprevention Trial. Gastroenterology 2007;132:490-97. (PMID 17258718)
32. Leman ES, **Schoen RE**, Weissfeld JL, Cannon GW, Sokoll LJ, Chan DW, Getzenberg RH. Initial Analyses of CCSA-3 and CCSA-4 as Colorectal Cancer Associated Serum Markers. Cancer Research 2007;67:5600-5. (PMID17575123)
33. Lieberman D, Nadel M, Smith RA, Atkin W, Duggirala SB, Fletcher R, Glick SN, Johnson CD, Levin TR, Pope JB, Potter MB, Ransohoff D, Rex D, **Schoen R**, Schroy P, Winawer S. Standardized colonoscopy reporting and data system: Report of the Quality Assurance Task Group of the National Colorectal Cancer Roundtable. Gastrointestinal Endoscopy 2007;65:757-66. (PMID 17466195)
34. Crespo S, Kuan SF, Ramanathan RC, **Schoen RE**. Gastric Polyposis in Familial Juvenile Polyposis. Gastrointestinal Endoscopy 2007;66:821-2. (PMID 17719585)
35. Gunter MJ, Hayes RB, Chatterjee N, Yeager M, Welch R, **Schoen RE**, Yakochi L, Schatzkin A, Peters U. Insulin resistance-related genes and advanced left-sided colorectal adenoma. Cancer Epidemiol Biomarkers Prev 2007;16:703-8. (PMID 17416760)
36. Berndt SI, Huang WY, Chatterjee N, Yeager M, Welch R, Chanock SJ, Weissfeld JL, **Schoen RE**, Hayes RB. Transforming growth factor beta 1 (TGFB1) gene polymorphisms and risk of advanced colorectal adenoma. Carcinogenesis 2007;28:1965-70. (PMID 17615257)
37. **Schoen RE**, Mutch M, Rall C, Dry SM, Seligson D, Umar A, Pinsky P. The Natural History of Aberrant Crypt Foci. Gastrointestinal Endoscopy 2008;67:1097-102. (PMID 18178205)
38. Ritenbaugh C, Stanford JL, Wu L, Shikany JM, **Schoen RE**, Stefanick ML, Taylor V, Garland C, Frank G, Lane D, Mason E, McNeeley SG, Ascensao J, Chlebowski RT, For the Women's Health Initiative Investigators. Conjugated Equine Estrogens and Colorectal Cancer Incidence and Survival: The Women's Health Initiative Randomized Clinical Trial. Cancer Epidemiol Biomarkers Prev 2008 (In press)
39. Ling BS, **Schoen RE**, Trauth JM, Wahed AS, Eury T, Simak DM, Solano FX, Weissfeld JL. Physicians Encouraging Colorectal Screening (PECS): A randomized controlled trial of enhanced office and patient management on compliance with colorectal cancer screening. Archives Intl Med 2009 (In press)
40. Berndt SI, Potter JD, Hazra A, Yeager M, Thomas G, Makar KW, Welch R, Cross AJ, Huang W, **Schoen RE**, Giovannucci E, Chan AT, Chanock SJ, Peters U, Hunter DJ, Hayes RB. *Pooled analysis of genetic variation at chromosome 8q24 and colorectal neoplasia risk*. Human Molecular Genetics 2008 (In press)
41. Pinsky PF, **Schoen RE**, Weissfeld JL, Church T, Yokochi LA, Doria-Rose VP, Prorok P. The Yield of Surveillance Colonoscopy by Adenoma History and Time to Exam. Clinical Gastroenterology and Hepatology 2009 (in press).
42. Croswell JM, Kramer BS, Kreimer AR, Prorok PC, Xu JL, Baker SG, Fagerstrom R, Riley TL, Clapp JD, Berg CD, Gohagan JK, Andriole GL, Chia D, Church TR, Crawford ED, Fouad MN, Gelmann EP, Lamerato L, Reding DJ, **Schoen RE**. Cumulative Incidence of False-Positive Results in Repeated, Multi-Modality Cancer Screening. Annals of Family Medicine 2009 (in press).
43. Leman ES, **Schoen RE**, Magheli A, Sokoll LJ, Chan DW, Getzenberg RH. Evaluation of colon cancer-specific antigen 2 as a potential serum marker for colorectal cancer. Clin Cancer Res. 2008;14:1349-54.
44. Gupta AK, Pinsky P, Rall C, Mutch MG, Dry S, Seligson D, **Schoen RE**. The Reliability and Accuracy of Endoscopic Appearance In The Identification of Aberrant Crypt Foci. Gastrointestinal Endoscopy 2009 (in press).
45. Mutch MG, **Schoen RE**, Fleshman JW, Rall CJN, Dry S, Seligson D, Charabaty A, Chia D, Umar A, Viner J, Hawk E, Pinsky PF. A Multi-Center Study of Prevalence and Risk Factors for Aberrant Crypt Foci. Clinical Gastroenterology and Hepatology 2009;7:568-74.
46. Laiyemo AO, Pinsky PF, Marcus PM, Lanza E, Cross AJ, Schatzkin A, **Schoen RE**. Use and Yield of Surveillance Colonoscopy in the Continued Follow up Study of the Polyp Prevention Trial. Clinical Gastroenterology and Hepatology 2009;7:562-7.

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C. Research Support

ACTIVE

N01-CN2551 (Weissfeld) National Cancer Institute "Prostate, Lung, Colorectal and Ovarian Cancer Screening Trial." This is a randomized, multi-center study to evaluate screening tests for their ability to reduce site-specific cancer mortality.	Period: 2002 - Present Direct Cost/yr: 33,750	25% Effort
2U01 CA 84968-01 (Bigbee) National Cancer Institute "Early Cancer Detection and Susceptibility Biomarkers" This is a proposal to develop biomarkers for early detection of colorectal cancer.	Period: 9/04 - 7/09 Direct Cost/yr: 72,000	15% Effort
P01 (CA73743-06) (Finn) National Cancer Institute "Dendritic Cell Biology and Therapy" The aims of this project are to test MUC1 vaccines in animal models and in human clinical trials.	Period: 02/07 - 06/09 Direct Cost/yr: 900,000	10% Effort
R01 (CA137088-01) (Peters) National Cancer Institute "Colorectal Cancer Genome-Wide Association Studies Consortium" The aim of this project is to perform a pooled analysis of genome wide association studies.	Period: 07/09 - 06/13 Direct Cost/yr: 11,698	5% Effort
Shire Pharmaceutical (Schoen) "PREVENT study" This is a randomized trial of mesalamine for prevention of recurrent diverticulitis.	Period: 03/08-03/11 Direct Cost/yr: 60,000	2% Effort

INACTIVE

NCI CPN0445 (Schoen) Randomized Phase II Trial of Atorvastatin, Raftilose, and Sulindac Among Patients at Increased Risk for Sporadic Colorectal Neoplasia This is a multi-center chemoprevention trial using Aberrant Crypt Foci as an intermediate endpoint.	Period: 09/05 – 09/08
NCI, N01-CN-25511 (Schoen) Prostate, Lung, Colorectal and Ovarian Cancer Screening Trial Special Study: Aberrant Crypt Foci This is an ancillary study of the PLCO screening trial examining the natural history, prevalence, and risk factors for aberrant crypt foci.	Period: 2003-2007

BIOGRAPHICAL SKETCH

NAME Carrie Farmer Teh	POSITION TITLE Associate Policy Researcher		
eRA COMMONS USER NAME carrieteht			
EDUCATION/TRAINING			
INSTITUTION AND LOCATION	DEGREE (if applicable)	YEAR(s)	FIELD OF STUDY
Wellesley College, Wellesley, MA	BA	1998	Psychobiology/ Spanish
Harvard University, Cambridge, MA	PhD	2006	Health Policy

A. Positions and Honors

Positions and Employment

2006-2009	NIMH Postdoctoral Fellow, Department of Psychiatry, University of Pittsburgh
2009-present	Associate Policy Researcher, RAND Corporation

Honors

2001-2004	NIMH Predoctoral Fellowship, NIMH/NRSA Training Program in Mental Health Policy, Harvard University
2005	New Investigator Award, NIMH Research Conference on Mental Health Services
2007	Scholar, Sixth Annual Career Development Institute (CDI) in Psychiatry, Sponsored by University of Pittsburgh and Stanford University

Professional Activities

Reviewer	<i>Journal of Clinical Psychiatry, Pain Medicine</i>
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B. Selected peer-reviewed publications

Peer-Reviewed Articles

Farmer CM, O'Donnell BF, Niznikiewicz MA, Voglmaier MM, McCarley RW, Shenton ME: Visual perception and working memory in schizotypal personality disorder. *American Journal of Psychiatry*. 2000; 157(5): 781-788.

Metman LV, Gillespie M, **Farmer C**, Bibbiani F, Konitsiotis S, Morris M, Shill H, Bara-Jimenez W, Mouradian MM, Chase TN: Continuous transdermal dopaminergic stimulation in advanced Parkinson's disease. *Clinical Neuropharmacology*. 2001; 24(3):163-169.

Verhagen Metman L, Morris MJ, **Farmer C**, Gillespie M, Mosby K, Wu J, Chase TN: Huntington's disease: A randomized, controlled trial using the NMDA-antagonist amantadine. *Neurology*. 2002 Sep 10;59(5): 694-9.

Reynolds CF, Cruz M, **Teh CF**, Rollman BL: Improving evidence-based depression care management for older Americans in primary care: if not now, when? *The Journal of the American Geriatrics Society*. 2008; 55(12): 2083-2085.

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Teh CF, Kilbourne AM, McCarthy JF, Welsh D, Blow FC: Gender differences in health-related quality of life for veterans with serious mental illness. *Psychiatric Services*. 2008;59: 663-669.

Teh CF, Morone N, Karp JF, Belnap BH, Zhu F, Weiner DK, Rollman BL. Pain interference impacts treatment for anxiety disorders. *Depression and Anxiety*. 2009; 26(3): 222-228.

Teh CF, Karp JF, Kleinman A, Reynolds CF, Weiner DK, Cleary PD: Older People's Experiences of Patient-Centered Treatment for Chronic Pain: A Qualitative Study. *Pain Medicine*. 2009; Published online 16 Jan 09.

Teh CF, Zaslavsky A, Reynolds CF, Cleary PD: Effect of depression treatment on medical and social outcomes for people with chronic pain, submitted for publication.

Teh CF, Sorbero M, Reynolds CF, Stein BD: Disparities in the adequacy of depression treatment among Medicaid-enrolled adults, submitted for publication.

Teh CF, Pincus HA, Welsh D, Kilbourne AM: Appropriateness of care for bipolar disorder among U.S. veterans, submitted for publication.

Published Abstracts

Farmer CM: "Depression Care Quality for People with Coincident Chronic Medical Conditions." Presented at the annual NRSA Trainees Research Conference, San Diego, 2004.

Farmer CM: "Depression Care Quality for People with Coincident Chronic Medical Conditions." Presented at NIMH Mental Health Services Research Conference, Bethesda, Maryland, 2005.

Teh CF, Belnap BH, Zhu F, Rollman BL: The impact of comorbid pain on treatment outcomes for a telephone-based collaborative care strategy for treating panic and generalized anxiety disorder. *Psychosomatic Medicine*. 2006; 68(1): A-64.

Teh CF, Belnap BH, Zhu F, Rollman BL: Prevalence and severity of comorbid pain among primary care patients with panic and/or generalized anxiety disorder. *Psychosomatic Medicine*; 2006; 68(1): A-110.

Teh CF, Cleary PD, Zaslavsky AM: "Effect of depression treatment on outcomes for people with chronic pain." Presented at AcademyHealth Annual Research Meeting. Seattle, Washington, 2006.

Teh CF, Sorbero M, Liang Q, Stein BD: "Quality of psychotherapy treatment for depression." Presented at NIMH Mental Health Services Research Conference. Washington, DC, 2007.

Teh CF, Karp JF, Kleinman A, Reynolds CF, Weiner DK, Cleary PD: "'When I was young you didn't ever contradict a doctor': older adults' experiences getting treatment for persistent pain in the age of patient-centered care." Presented at AcademyHealth Annual Research Meeting. Orlando, Florida, 2007.

Teh CF, Kilbourne AM, McCarthy JF, Welsh D, Blow FC: "Gender differences in health-related quality of life for veterans with serious mental illness." Presented at AcademyHealth Annual Research Meeting. Orlando, Florida, 2007.

Teh CF, Sorbero M, Liang Q, Stein BD: "Quality of psychotherapy treatment for depression." Presented at National Association of State Mental Health Program Directors Research Institute Annual Conference. Washington, DC, 2008.

Zeber JE, Miller AL, Velenstein M, McCarthy JF, Zivin K, **Teh CF**, Cruz M, Kilbourne AM: "Medication adherence, ethnicity, and the influence of multiple psychosocial and financial barriers in veterans with bipolar disorder." Presented at VA HRS&D National Meeting. Washington, DC, 2008.

Teh CF, Welsh DE, Lasky E, Kilbourne AM: "Assessing patient-centered quality of care for VA patients with bipolar disorder." Presented at the VA HSR&D National Meeting. Baltimore, MD, 2009.

C. Research Support

Quality of Depression Care for the Chronically Ill

Ruth L. Kirchstein National Research Service Award, National Institute of Mental Health (F31 MH073225)
PI, 9/2004-9/2006

Clinical Research Training in Psychiatry

National Institute of Mental Health (T32 MH19986)
Fellow, 9/2006-1/2009

Quality of Psychotherapy for Depressed Medicaid-Enrolled Adults

Community-Academic Partnership Award, \$9,000
PI, 12/2006-12/2007

Assessing the Quality of Depression Care among Medicaid-Enrolled Adults Using Chart Abstraction

RAND-University of Pittsburgh Health Policy Institute/ WPIC (RUPHI), \$25,000
PI, 7/2008-7/2009

1. SPECIFIC AIMS

One barrier to improving the quality of clinical care is the shortage of readily available quality measures. To date, quality of clinical care has generally been measured using manual record reviews or analysis of administrative claims, both of which have key limitations. Administrative claims lack the clinical detail to understand most aspects of quality that are important to providers and patients. Manual medical record reviews are time-consuming and resource intensive. Recent advances in health information technology, however, may provide opportunities for routine clinical quality measurement. Health systems are increasingly using electronic medical records (EMR) to capture encounter data, and semi-automatic natural language processing (NLP) tools have been developed to translate free text into structured data. This creates the possibility of creating a new method for measuring quality of care.

We propose to develop a NLP based program (the C-QUAL tool) to assess the quality of follow-up recommendations after screening colonoscopies. There is evidence that screening colonoscopy is inappropriately performed and in excess of guidelines, which in turn harms access to care and increases healthcare costs. Colonoscopy reports are ideal for NLP analyses because they are usually in electronic form and have a clear structure (e.g. indication, findings, recommendations) which facilitates analysis.

Specific Aim 1: Use NLP technology to develop a tool (C-QUAL) to extract from colonoscopy reports and associated clinical records the eight necessary data elements to determine whether gastroenterologists' follow-up recommendations for next colonoscopy are consistent with guidelines.

Specific Aim 2: Using a sample of 250 colonoscopy reports and associated clinical records, test the C-QUAL tool versus the gold standard of manual extraction by a clinical expert of the same eight data elements.

Our goal is to use the data generated via the specific aims as the preliminary data for an R01 in which we will use the C-QUAL tool to analyze a national sample of colonoscopy reports to quantify compliance with guidelines and identify to assess physician and patient factors that influence compliance with guidelines.

2. BACKGROUND AND SIGNIFICANCE

2.1. One key barrier in improving the quality of clinical care is the shortage of readily available quality measures

In a landmark report published in 2001, the Institute of Medicine (IOM) reviewed several hundred studies on healthcare quality.¹ In summarizing their findings, the IOM described a chasm between the care patients receive and what the healthcare literature says they should receive. In the single most comprehensive evaluation of the care of almost 7,000 adult patients, McGlynn and colleagues found that only 55% of recommended care was provided.² Despite this large body of evidence, it is believed that healthcare providers still do not devote enough resources to quality improvement.³ The IOM has described many barriers to improving quality in a series of reports. One key barrier is the shortage of available quality metrics that can be used to provide feedback to physicians.⁴

2.2. Key weaknesses in administrative claims analysis and medical chart review

To date, quality of clinical care has generally been measured using manual record reviews or analysis of administrative claims, both of which have key limitations. Administrative claims often lack the clinical detail to understand many aspects of quality that are important to providers and patients.⁵ Medical record reviews can provide the level of clinical detail necessary to adequately evaluate quality of care, but current methods are time-consuming and expensive, and therefore not routinely feasible on a large scale.⁶

2.3. Growing use of EMR has not solved the quality measurement problem

With increasing use of EMRs, the US healthcare system will create enormous amounts of electronic data on health services use and health outcomes. Initially, there was an assumption among policy makers that quality measurement using an EMR would be easy. In some cases the EMR has facilitated quality measurement related to structured data such as vital signs, laboratory data, and medications. But much of the rich data in an EMR is inputted via free text or dictation and is therefore not structured. For example, a physician might write in a visit note that they “counseled patient on smoking cessation.” Because this key piece of information does not exist in a structured format, it is hard to extract. There is a need for more sophisticated methods for extracting key clinical information from free-text records.

2.4. Development of Natural Language Processing tools as applied to healthcare

Natural language processing (NLP) is a field of computer science that tries to convert human language into more structured data. This is done through parsing sentences into pieces and then using algorithms that address the vagaries of English language such as grammatical context, use of synonyms, acronyms, and slang. NLP is used in a wide variety of applications including helping with internet search engines and automating translation of text into a different language.

The use of NLP in healthcare for semi-structured text (such as EMRs) has become increasingly sophisticated.⁷ Tools have been developed that help with extraction of specific treatments, drugs, signs, symptoms, or diagnoses. Similarly, programs have been able to address grammatical issues specific to medical text such as co-occurring symptoms and the unusual use of negation (e.g. “patient denied any problems.”)

There are many examples of healthcare NLP research. Colleagues at the University of Pittsburgh have used NLP to automatically classify chief complaints.⁸ Others have used NLP to detect adverse events during a hospitalization,⁹ to determine whether physicians discussed smoking cessation at an office visit,¹⁰ and to find out whether patients with diabetes have had an annual foot examination.¹¹ Applying NLP to the measurement of quality of colonoscopy reports has not been attempted, yet this use of NLP could have significant impact on healthcare outcomes and costs.

2.5. Concerns about colonoscopy follow-up

There are an estimated 150,000 cases of colorectal cancer diagnosed annually in the US, and colonoscopy is a mainstay of colorectal cancer screening.¹² For patients with no lesions detected at the colonoscopy, follow-up colonoscopy is recommended in 10 years.¹³ Certain lesions, such as large adenomas (1 cm or larger), are detected in approximately 5-10% of screening colonoscopy procedures, and in these cases, earlier follow-up colonoscopy is recommended. Clinical practice guidelines for adenoma surveillance typically recommend colonoscopy at three years after finding a large adenoma or three or more small adenomas and at five years after detection of one or two small adenomas. Early surveillance is not recommended for hyperplastic polyps.

There is concern that in persons with lesions that do not confer an increased future risk for colorectal cancer, such as hyperplastic polyps or small adenomas, surveillance may be over performed. Surveys have found that half of gastroenterologists and surgeons recommend earlier follow-up than what is recommended in clinical guidelines.¹⁴ In a study led by Dr. Schoen, a co-principal investigator on this grant, surveillance colonoscopy use was monitored in a cohort of patients and found to be overutilized among low-risk patients.¹⁵ Because of limited colonoscopy capacity, overuse may restrict access to colonoscopy for those that need it.¹⁶ Overuse also leads to excessive patient risk¹⁷ and inappropriate use of resources.¹⁵

A tool that allows one to measure consistency of physicians’ recommendations with clinical guidelines could have many applications. First, it can be used to automate feedback to physicians on their compliance with research-based guidelines. Second, it can be used to study questions such as what is the association of guideline compliance with specialty, years of practice, or volume of procedures.

2.6. Advantages of Colonoscopy Reports For NLP Analysis

Colonoscopy reports have several key advantages as one of the first applications of NLP to measure healthcare quality. Most colonoscopy reports are already generated in electronic format as opposed to being hand-written. Second, the notes generally have a clear structure (e.g. indication, findings, recommendations). This makes it easier for us to develop a new NLP based program to extract relevant information. Third, the amount of clinical data necessary to judge compliance with guidelines is limited. Lastly, there is clear policy interest in the area.

3. RESEARCH DESIGN AND METHODS

The goal of this project will be to develop a NLP-based computer tool (“C-QUAL”) that will extract from colonoscopy reports (and associated clinical data) relevant data to evaluate whether recommended follow-up is consistent with published guidelines. We will then test the performance of the tool using a test sample of 250 colonoscopy reports against the gold standard of a manual evaluation of the same reports by clinical experts.

3.1. Data sources

For both the development and testing of the C-QUAL tool we will use data from the University of Pittsburgh’s Medical Archival System (MARS). MARS includes clinical data of patients seen at the University of Pittsburgh Medical Center’s (UPMC) twenty hospitals, four long-term care facilities, physician offices, and outpatient clinics. Longitudinal profiles of patient events can be created with direct links to all the elements of the clinical electronic record. Data from MARS has been used in many previous NLP projects.^{8, 18-21} All records will be de-identified using the De-ID program.²²

The MARS system contains 45,239 colonoscopy reports from the last two years. From this sample, we will create two unique random data samples. The first will be a training sample which will be composed of 1000 colonoscopy reports. The second will be a testing sample which will be composed of 250 colonoscopy reports. We will only select colonoscopies conducted for screening. Colonoscopy reports in both samples will be linked to any relevant pathology reports and clinical notes.

3.2. Measuring consistency of follow-up recommendations with clinical guidelines

In 2008, the American Cancer Society, the US Multi-Society Task Force on Colorectal Cancer, and the American College of Radiology published an updated guideline on “Screening and Surveillance for Early Detection of Colon Cancer and Adenomatous Polyps.” Figure 1 on the next page summarizes the recommendations.

3.3. Necessary data elements that need to be extracted from clinical records

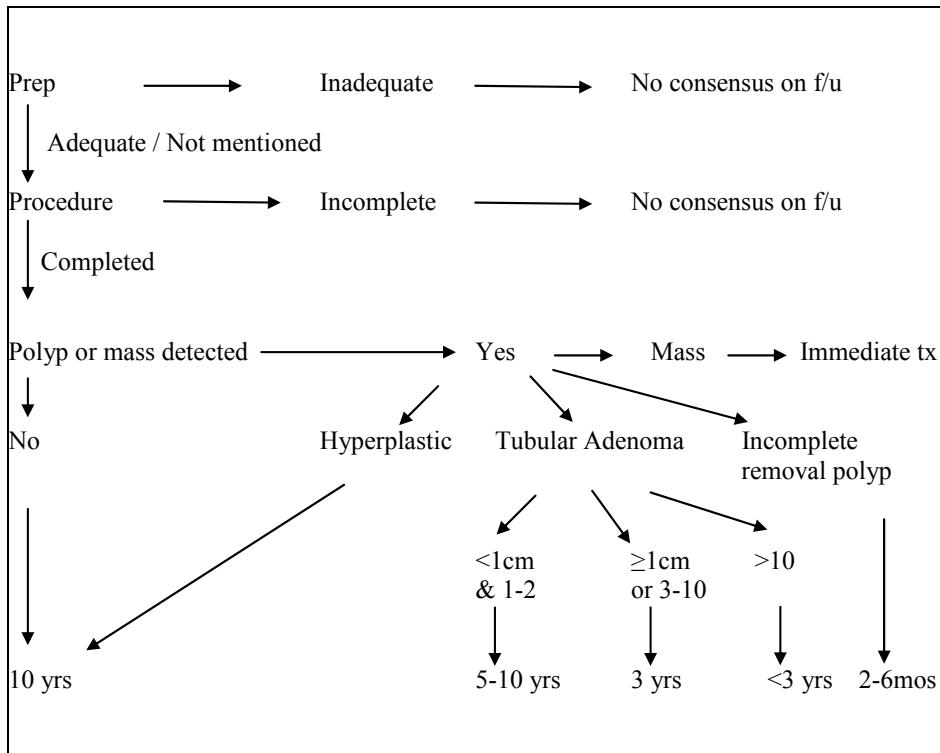
The eight data elements that we plan to extract from the colonoscopy report and associated clinical data are listed in Table 1. Age, gender, and insurance type are available using other data sources.

Table 1. Eight Key Data Elements to Be Extracted

<i>Data Element</i>	<i>Why it is important to extract</i>
Indication for procedure	Identify colonoscopies done for screening purposes as opposed to another indication (e.g. bleeding).
Previous history polyps, inflammatory bowel disease	Influences follow-up recommendation.
Family history of colorectal cancer	Influences follow-up recommendation.
Adequacy of bowel preparation	Judgment of whether physician can adequately visualize colon. With inadequate preparation follow-up is left to judgment of physician.

Completion of procedure	Complete procedure requires visualization of cecum with the appendical orifice and ileocecal valve. With incomplete procedure follow-up is left to judgment of physician.
Detection of polyps	Size and number are key determinants of follow-up.
Pathology of polyps	Pathologic subtype (hyperplastic vs. adenoma) key determinants of follow-up.
Recommendations for follow-up	Main outcome of interest

Figure 1: Follow-up on recommendations for follow-up post-colonoscopy



Note: Even when no polyps are found, shorter follow-up may be necessary with family history of colorectal cancer, inflammatory bowel disease, or history of polyps. These are among the eight key data elements to be extracted from reports.

3.4. Key challenges in extracting data elements

Though the proposed work is more straightforward than many applications of NLP techniques, we recognize that we will face some scientific challenges in extracting the eight key data elements. Follow-up recommendations frequently depend on the pathological evaluation of any removed polyps which can take several days after the colonoscopy is completed to become available. After they receive the pathology report, physicians vary in what format (e.g. letter to patient, addendum to colonoscopy report) they use to report their follow-up recommendations. The linkage of a colonoscopy report to pathology reports and follow-up clinical notes is straightforward but increases the complexity of the NLP analysis.

Like all electronic medical records, colonoscopy reports contain a very wide variety of textual styles of information. Some text in the record comes from direct clinician data entry, other comes from transcriptions of clinician dictation, and either can be lengthy. In all cases, the text has not been edited for grammatical structure, making it a challenge to standard statistical parsing techniques. Clinicians are trained to record medical record information in a highly stylized and technical language. This language, while efficient for the clinician, poses challenges for natural language processing. Clinicians may list the presence or absence of

evidence in a terse style, for example “FH neg” and “prep adeq.” In addition, physicians use a variety of terms to describe the same finding (preparation is described as “suboptimal,” “inadequate,” “fair”). The use of negatives is also sometimes hard for a computer to parse (“past medical history of polyps” vs. “previous history of no polyps” vs. “no notable history of polyps”). All of these are challenges the NLP experts on the team have addressed in previous projects, but do make the programming more difficult.

3.5. Aim 1 – Creating the C-QUAL tool

The NLP pipeline we propose to develop for this project consists of four major stages. The first stage preprocesses a colonoscopy report by “tokenizing” its text into units of decreasing granularity, specifically: words, sentences, paragraphs, and sections. All subsequent stages in the pipeline rely on proper identification of these units. For the tokenization tasks we will use modules from Topaz, a commonly used NLP program.¹⁹

The next stage is named entity recognition: the identification of mentions of relevant entities in the text of a report, such as diseases, symptoms, findings, diagnoses, and interventions. This design and implementation of stage will be based on the UMLS Metathesaurus, which is a publicly available collection of interrelated vocabularies covering the biomedical and clinical fields.²³ The Metamap program recognizes meaningful strings in text and maps these onto concepts in the Metathesaurus taking into account acronyms, synonyms and term variation.²⁴

The third stage in the pipeline identifies sentences in the text of a colonoscopy report that contain information relevant to the key data elements to be extracted.²⁵ To identify informative sentences, we will train a set of statistical classifiers that will quantify to what degree a sentence is likely to contain information about the indication for a colonoscopy, recommendations for follow-up, presence of a polyp, etc;. The predictive features used in the classifiers will include the named entities present in a sentence as well as other informative words such as verbs, and the section the sentence occurs in. An approach using classifiers is more flexible than keyword detection and will be applicable across different types and formats of reports.

In the fourth and final stage the sentences that have been determined relevant in the previous stage are processed to extract the information corresponding to the key data elements. The techniques employed in this stage depend on the nature of the information to be extracted. Some of the data elements represent properties of entities, e.g., the adequacy of the preparation and whether there is a family history of colon cancer. Our previous work has shown that this type of information can reliably be extracted by looking for trigger words such as “family history” and “inadequate” in the context of the entity of interest.²⁶ Other data elements denote more complex information and necessitate the formulation and application of more articulate grammatical patterns that describe the various ways in which the information can be expressed in a sentence.

We will supplement both information extraction approaches with a semi-supervised learning component.²⁷ Given a small number of good trigger terms or grammatical patterns and a set of reports, the learning component will automatically find similar words and patterns that can be used to extract information.

3.6. Aim 2 – Evaluating the performance of the C-QUAL tool

In Aim 2, we will test the performance of the C-QUAL tool. We will use the test sample of 250 colonoscopy reports and associated pathology and clinical notes. The sample size of 250 is consistent with other evaluations of NLP based tools.^{20,21} Independently the eight key elements will be extracted by both the C-QUAL tool and manual review from an expert clinician. To judge level of agreement, we will calculate area under the curve (AUC) of the receiver operator characteristic (ROC) curves using trapezoidal integration. We will also measure the chance-corrected agreement between C-QUAL and the clinician using the kappa statistic.

4. How results from this pilot grant will be used in a larger NIH RO1 proposal

The results from this pilot grant will be used for future projects, both in the short term and long term. In the short term, the results from the study will serve as the primary preliminary data for an RO1 application to the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK) to better understand the variation in colonoscopy follow-up. We will use the C-QUAL tool to analyze colonoscopy follow-up reports from several large medical systems across the nation such as Kaiser, University of North Carolina, and the Clinical Outcomes Research Initiative national endoscopic database. The goal of this larger study would be to determine overall compliance with guidelines and understand factors that influence compliance with guidelines. Factors to be studied include physician factors (e.g. academic vs. private practice, volume of colonoscopy), patient factors (e.g. age, type of insurance, severity of illness), and regional factors (e.g. availability of colonoscopy, high spending vs. low spending area). Part of the larger project will be to refine the C-QUAL tool for varying clinical systems. Our hope is that more widespread use of the C-QUAL tool will improve clinical practice by increasing compliance with research-based clinical guidelines.

In the longer term, we hope this pilot study lays the foundation for a broader set of studies on how to use NLP techniques to measure the quality of care. For example, a co-principal investigator, Carrie Teh, has recently submitted a proposal to use NLP based tools to measure the quality of psychiatric care.

As the US healthcare system evolves to an information technology infrastructure with increasing use of EMRs, enormous amounts of electronic data on health services use and health outcomes will be created. To take advantage of these data for research on best practices and comparative effectiveness, it is necessary to develop technologies and tools for extracting and using large amounts of text-based information. Researchers to date have used human abstractors to systematically read patients' charts and EMRs and manually extract clinical information. However, this approach limits the number of clinical encounters that can be feasibly examined, limiting its utility. The innovative NLP technique proposed in this study has the potential to allow researchers to address a wide range of questions about quality of care, healthcare use, and costs for the first time.

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Program Director/Principal Investigator (Last, First, Middle): Mehrotra, Ateev

DETAILED BUDGET FOR INITIAL BUDGET						FROM	THROUGH	
PERSONNEL <i>(Applicant organization only)</i>		Months Devoted to Project			INST.BASE SALARY	DOLLAR AMOUNT REQUESTED <i>(omit cents)</i>		
NAME	ROLE ON PROJECT	Cal. Mnths	Acad. Mnths	Summer Mnths		SALARY REQUESTED	FRINGE BENEFITS	TOTAL
Ateev Mehrotra	PD/PI							
Carrie Farmer Teh		.72						7,942
Robert Schoen		.48						10,423
Hendrik Harkema		2.4						11,000
SUBTOTALS →								29,365
CONSULTANT COSTS								
EQUIPMENT <i>(Itemize)</i>								
SUPPLIES <i>(Itemize by category)</i>								
TRAVEL								
PATIENT CARE COSTS		INPATIENT						
		OUTPATIENT						
ALTERATIONS AND RENOVATIONS <i>(Itemize by category)</i>								
OTHER EXPENSES <i>(Itemize by category)</i>								
MARS data \$300								
								300
CONSORTIUM/CONTRACTUAL COSTS					DIRECT COSTS			
SUBTOTAL DIRECT COSTS FOR INITIAL BUDGET PERIOD <i>(Item 7a, Face Page)</i>								\$ 29,965
CONSORTIUM/CONTRACTUAL COSTS					FACILITIES AND ADMINISTRATIVE COSTS			
TOTAL DIRECT COSTS FOR INITIAL BUDGET PERIOD								\$ 29,965